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Studies in Ecology of Coronary Heart Disease

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I. Variations in the Human Electrocardiogram Under Conditions of Daily Life (A Preliminary Report)

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Cardiologists have long known that physical activity, changes in position, and certain bodily functions such as digestion and sleep may be associated with changes in the electrocardiographic complex. Since it has been postulated that some of the changes that occur under such circustances are indicative of cardiovascular disease, and that certain occupations or activities may accelerate or even cause the occurrence of coronary heart dissease, it has become important to have a more thorough understanding of the range of variation of the human electrocardiogram under a variety of ordinary conditions. We have taken advantage of recently developed methods for monitoring the electrocardiogram and are making a systematic effort to obtain a more exact picture of the nature, the degree, and the frequency of the changes that occur under the conditions of daily life.

Method

The phenomena that are here described have been observed during the study of some 300 ambulatory, ostensibly healthy men and women between the ages of 20 and 60, of whom 200 were members of a randomly designated cohort of actively employed men in their 50's. This study is still underway. Each subject is being observed throughout one day of carefully controlled and carefully timed activity in our laboratories. After a night's sleep in comfortable quarters provided by us, systematic recordings are being obtained under the following conditions.

1. With the subject rested, fasting, and supine
2. With the subject in the left and right lateral decubitus, the knee-chest position, seated, and standing
3. During the Valsalva maneuver
4. During the Master's test [1]
5. During the ingestion of 500 cc of ice water, followed by 500 cc of hot coffee
6. During three brief walks in the outside air of 175, 125, and 125 meters each (the ambient temperature has ranged from —4 C [25 F] to 24 C [75 F], depending on the season, with extremes from —12 C [10 F] to 32 C [90 F])
7. During three hours of moderately challenging and anxiety-producing psychological tests and interviews
8. During the ingestion of a high caloric meal of large bulk, followed by 360 cc (12 oz) of a carbonated beverage
9. While walking up a flight of 13 stairs and over 125 meters of level ground immediately after this meal
10. During the afternoon, after a day of continued sedentary activity to the point of moderate fatigue

Additional, but less systematic, recordings have been obtained under a variety of other conditions throughout the day and during and after a large meal in the evening, as well as during sleep. Each step in the procedure is timed by stopwatch. A thorough medical history and cardiac diagnostic examination is carried out on each subject, as well

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as various laboratory investigations primarily concerned with fat transport.

The ECG is monitored by means of the miniaturized battery-powered tape recorder, developed by Holter et al.[2] This apparatus will record one lead of the ECG over a ten-hour period. The electrodes are placed over the fifth rib in the nipple line bilaterally. The lead used is bipolar and has the general characteristics of lead I, although, because of the position of the electrodes, it has the appearance of V_5.

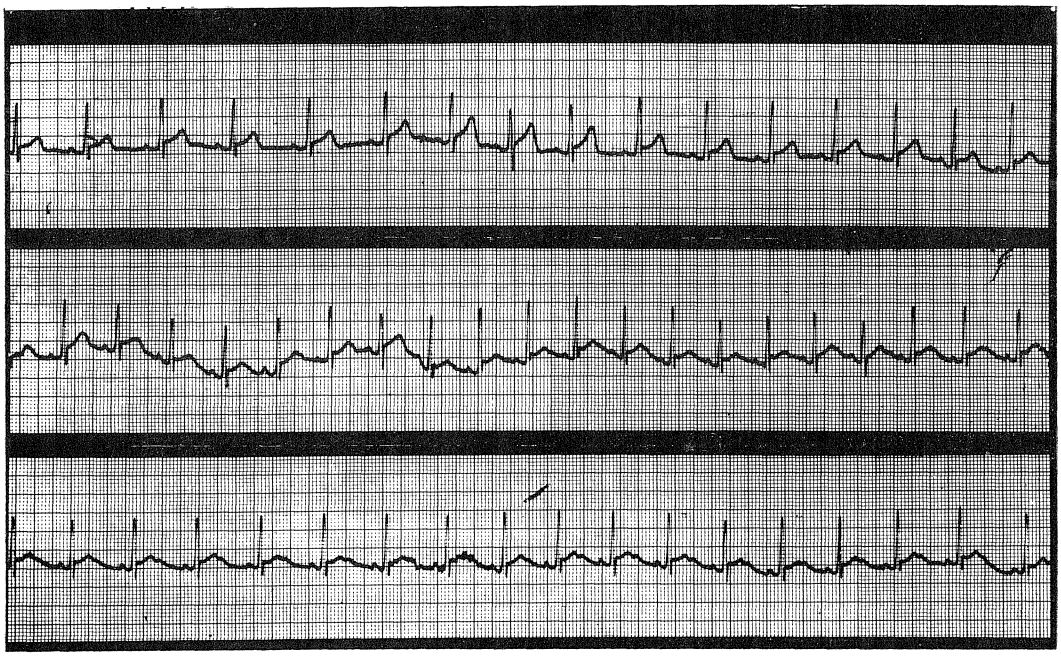
The data are analyzed by displaying the ECG complexes on an oscilloscope screen, superimposed on each other at 60 times "real-time." This produces a "moving picture" of the ECG, in which ten hours of data are displayed in ten minutes. Any desired segment of the complex may be photographed, diagrammed, or written out at real-time as a standard ECG. The cardiac rate and rhythm are analyzed by displaying the RR intervals as vertical bars on a calibrated oscilloscope screen.

Preliminary Findings

Although the majority of the young people thus far observed have relatively stable complexes, nearly all have displayed a loss of amplitude of the T -wave upon arising from a sitting position, or on the Valsalva maneuver. The ingestion of hot and cold fluids has had little effect upon this lead of the ECG. The Master's test shortens the QT time and usually causes the T -wave to lose amplitude as the heart rate increases. Walking 175 meters in the outdoor air has an effect as great as that of the Master's test. As a large meal is ingested, the T -wave loses amplitude and the rate increases. Walking up a flight of stairs after the meal accentuates this effect. Nearly all young people have shown a moderate phasic variation of heart rate with respiration. In the afternoon after a large meal, the heart rate is consistently 10 to 20 beats per minute greater than in the morning.

Approximately one third of the young men thus far observed have had more labile complexes. When they are in the standing position or performing the Valsalva maneuver, their T waves may become notched or inverted (Fig. 1). On the Master's test, the ST segments may become slightly depressed. Walking 175 meters in the outdoor air has a similar effect. While they are ingesting a large meal, their T wave may become flattened, notched, or inverted. When they walk up a flight of stairs after the meal, their ST

Fig 1.—A man of 23: notching of T wave as subject arises from a sitting position (real-time write-out from taped record).



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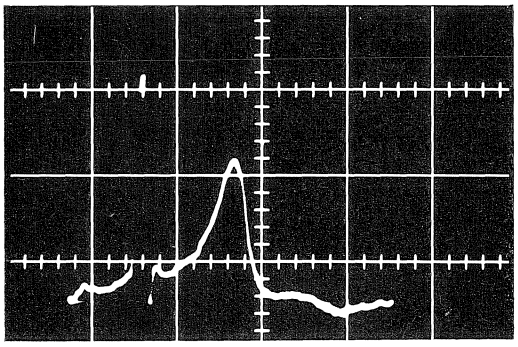


Fig 2.—A man of 23: morning record, sedentary activity.

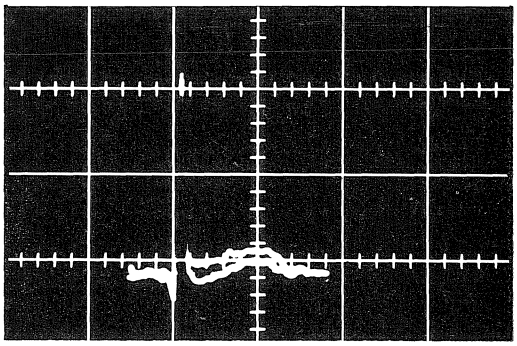


Fig 3.—A man of 23: after ingesting a large meal.

segments may become noticeably lower, and sometimes depressed, and this may persist for a short while (Fig. 2 and 3).

An equal or greater proportion of healthy young women appear to have unstable complexes. Their T waves invert on standing or

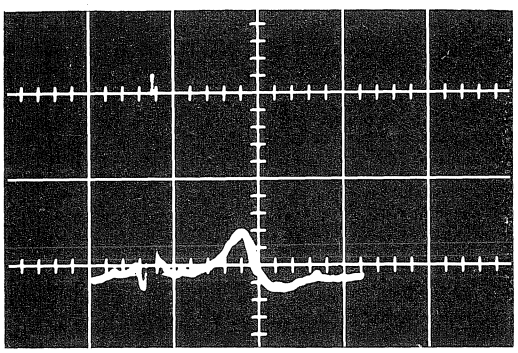


Fig 4.—A woman of 20: morning record, sedentary activity.

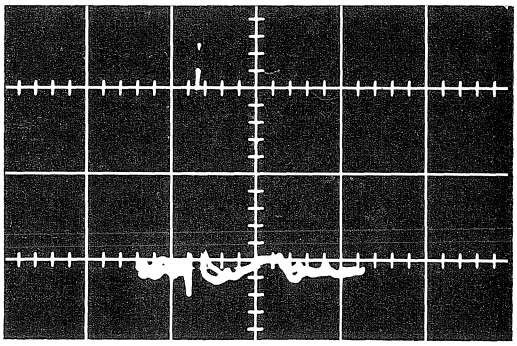


Fig 5.—A woman of 20: walking up a flight of stairs after a large meal.

Fig 6.—A woman of 20: inversion of T waves occurring during Valsalva maneuver (real-time write-out from taped record).

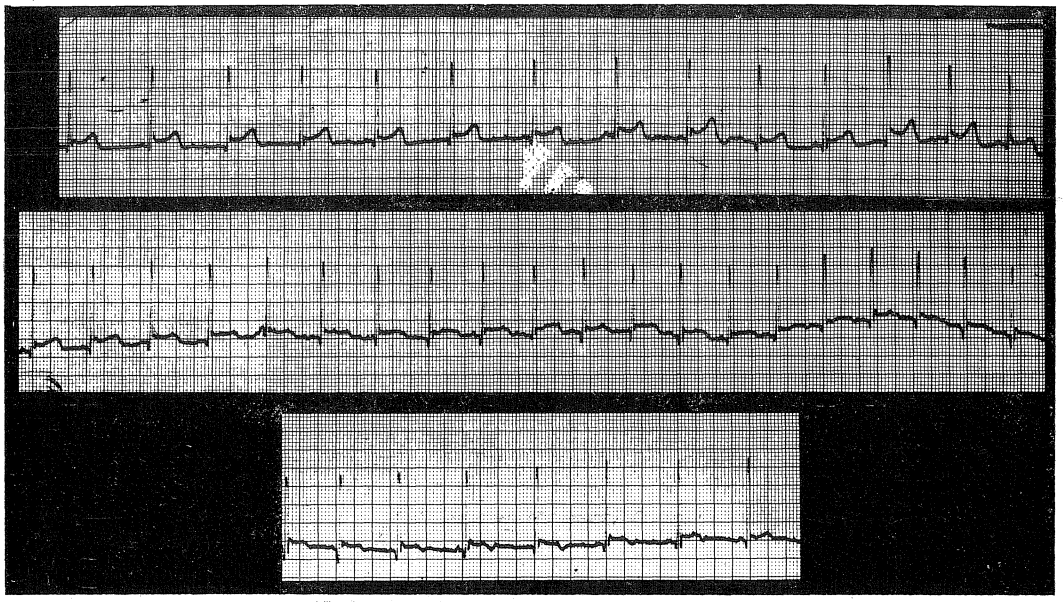


Fig 2, 3, 4 and 5 are photographed from oscilloscope.

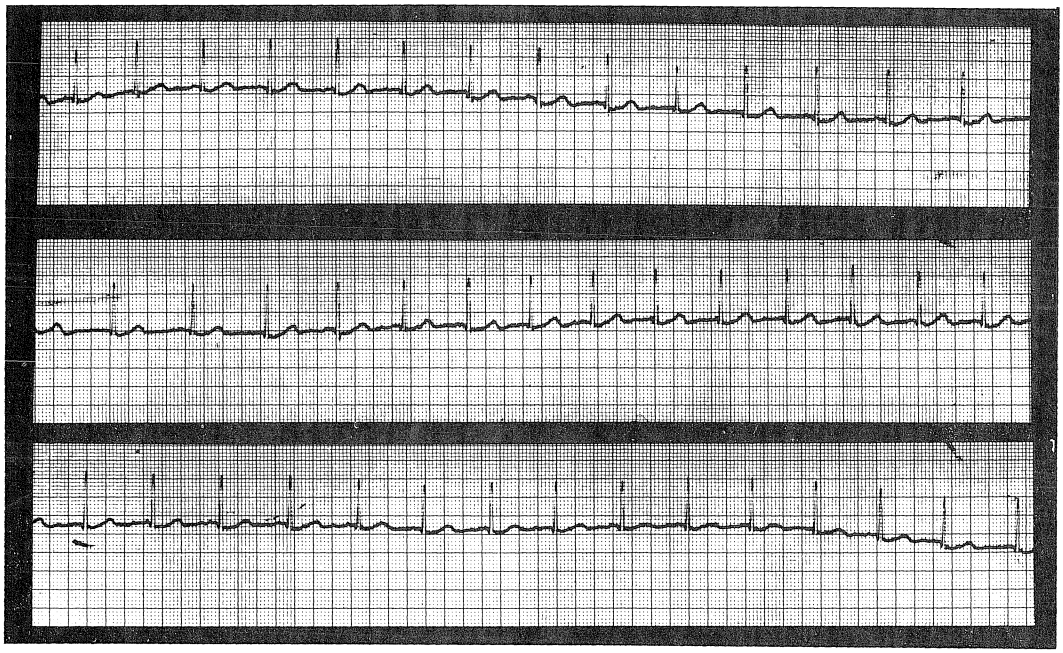


Fig 7.—A woman of 20: depression of ST segment occurring after Master's test (real-time write-out from taped record).

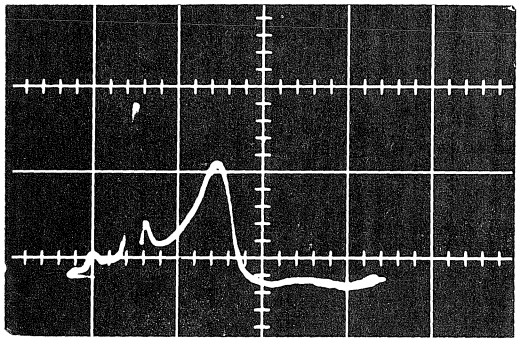


Fig 8.—An asymptomatic man of 35 without evidence of cardiovascular disease; morning record, sedentary activity (photographed from oscilloscope).

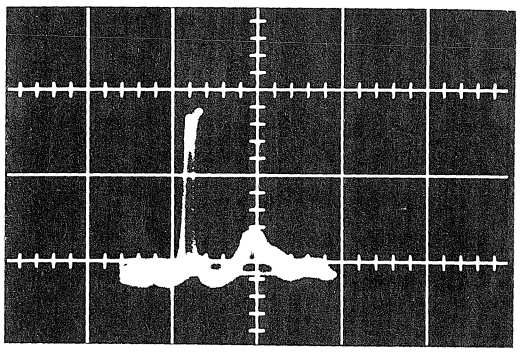


Fig 9.—An asymptomatic man of 35 without evidence of cardiovascular disease: during a period of moderate activity (photographed from oscilloscope).

Fig 10.—An asymptomatic man of 35 without evidence of cardiovascu'ar disease: walking up a flight of stairs after a large meal (photographed from oscilloscope).

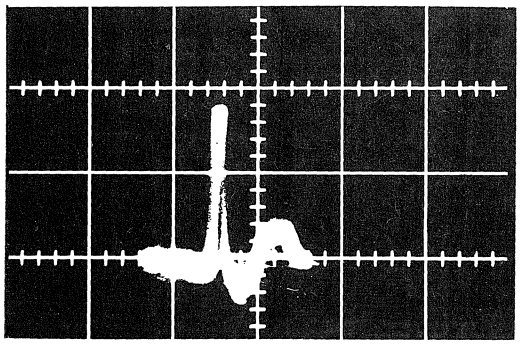
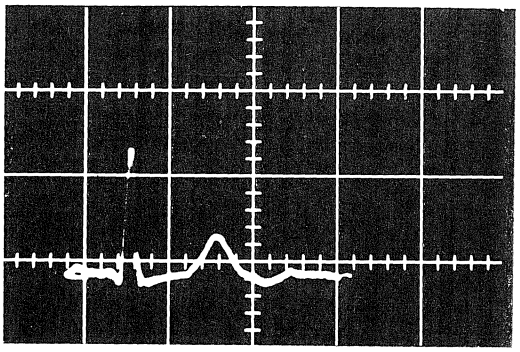


Fig 11.—A man of 56: morning record, sedentary activity (photographed from oscilloscope).



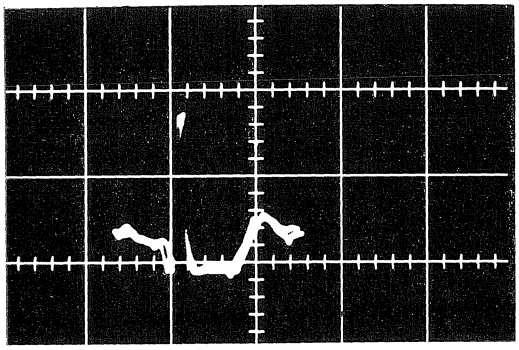


Fig 12.—A man of 56: persistent asymptomatic depression of ST segment occurring during the afternoon after a large meal (photographed from oscilloscope).

on the Valsalva maneuver. They show a marked rise in heart rate and slight depression of the ST segment on the Master's test. Similar or even more marked changes occur when they ingest a large meal and then walk up a flight of stairs (Fig. 4-7).

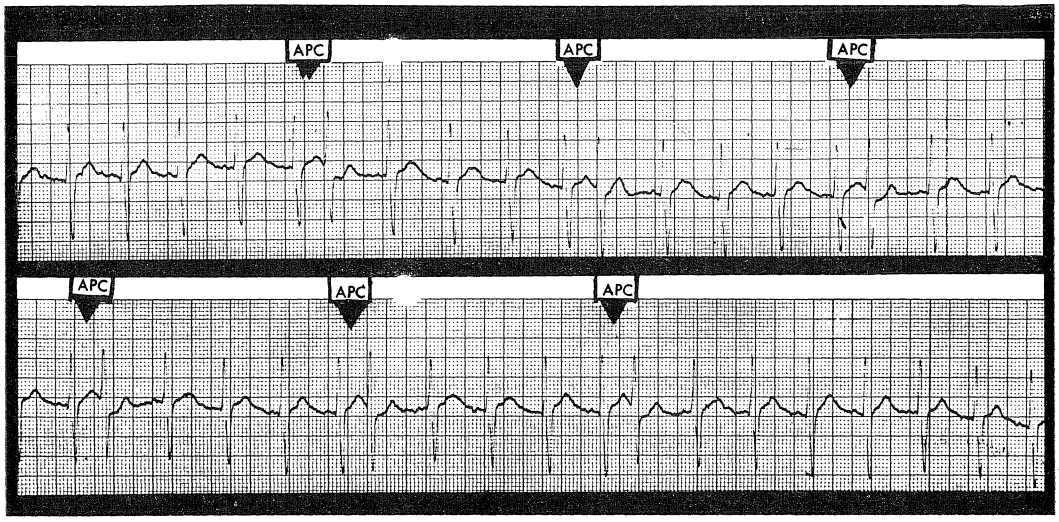
In some subjects, the electrocardigraphic complex undergoes a regular evolution during the course of a day. In the morning, with the subject rested and moderately active, the complex has a "healthy," "normal" appearance. In the afternoon, after a busy day, the T wave is lower and tends to become notched or inverted. As the tired subject ingests a large dinner, the T wave may invert entirely and the ST segment may become depressed. These changes persist during the evening. However, after 20 minutes of restful sleep, the T wave is again upright, and after six hours of sleep, the complex has resumed its healthy, normal appearance.

In men in their 30's and 40's, electrocardiographic changes with position, diet, and activity have seemed to be more pronounced and persistent than they are in younger men. During a large meal, the T wave may become quite flat and notched. A pronounced ST sag may develop after the meal and persist during the afternon (Fig. 8, 9, and 10).

These effects seem to be even greater and more persistent among older men. For example, a man of 56, with a blood pressure of 160/90 and a history of some "atypical chest pain" in the past, had only slight changes in a standard exercise test. Walking 175 meters in the outdoor air produced an alarming sag in his ST segment, but no symptoms. After a large meal and climbing a flight of stairs, he exhibited a "distinctly pathological" ECG (Fig. 11 and 12). This persisted all afternoon, but at no time did he have any symptoms or appear to be in any way distressed. Phenomena such as this have been observed repeatedly.

Atrial premature contractions have been observed to occur at all ages, but they are less common than ventricular premature contrac-

Fig 13.—A man of 56: atrial premature contractions occurring during an attack of asthma (real-time write-out from taped record).



tions. They seem to show a distinct association with pulmonary disease (Fig 13).

Ventricular premature contractions are very common. Most men in their 50's have been found to have from one to five ventricular premature contractions per hour, and some have as many as 400 per hour. They often increase with anxiety, and after a large meal, they may become very frequent and appear in pairs or bursts (Fig. 14).

Not infrequently, we have observed striking electrocardiographic changes in ostensibly healthy men in their 50's. Such a man may have no history of cardiovascular disease. His standard ECG is normal, and after a careful examination by a cardiologists, it has been decided that he has no clinical evidence of cardiac disease. Yet, a short walk in the outside air produces a noticeable ST segment depression. Psychological tests bring forth bursts of ventricular premature contractions, many of them followed by T wave inversion. A large meal greatly accentuates these changes, which persist throughout the afternoon. Yet the subject remains asymptomatic throughout all of this.

Striking changes in intraventricular conduction have also been observed with considerable frequency in asymptomatic middle-aged men. For example, an asymptomatic man, whose only known cardiovascular disorder was a modest grade of hypertension, displayed alternately right bundle branch block, left bundle branch block, and normal intraventricular conduction. The normal intraventricular conduction was usually associated with two to one atrioventricular block and a more rapid atrial rate. Throughout most of the day, this alternated with slower sinus rhythm accompanied by right bundle branch block and normal atrioventricular conduction (Fig 15).

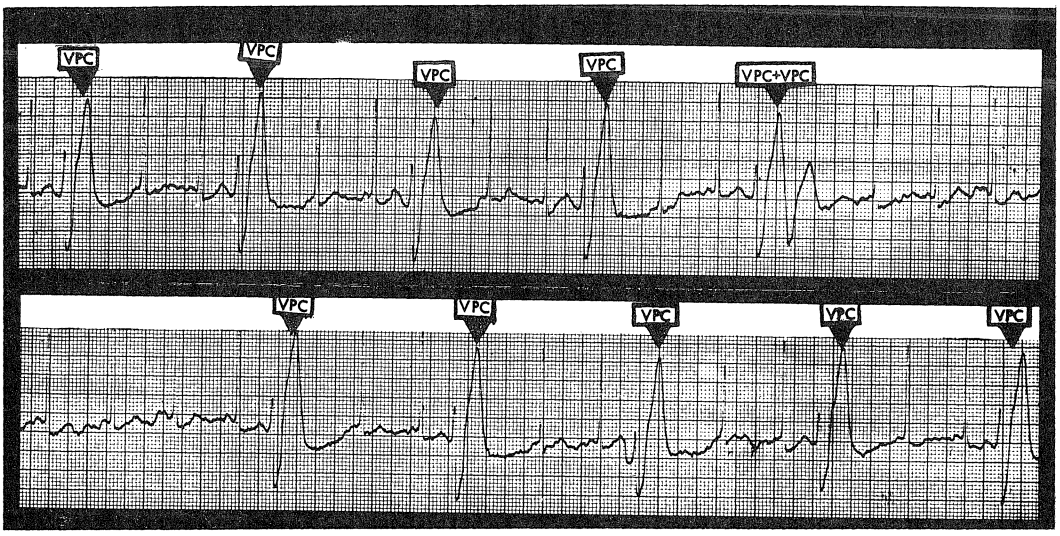
A number of men who have developed anginal pain on the Master's test, on walking 175 meters outdoors, and after a large meal, have had electrocardiographic changes less pronounced than those of many men who remained asymptomatic throughout the day.

Some men, whose electrocardiograms show ST segment depressions and inverted T waves in the morning, have developed upright T waves, often without segment depression, after exercise or after a large meal.

During follow-up studies, some men who have been discovered to have abnormal ECG's have later been observed to develop myocardial infarction.

A significant proportion of men in this age group have had electrocardiographic complexes as stable as that of young men in their 20's. On the Master's test, on walking 175 meters in the open air, after

Fig 14.—A man of 58: burst of ventricular premature contractions occurring during a period of anxiety (real-time write-out from taped record).



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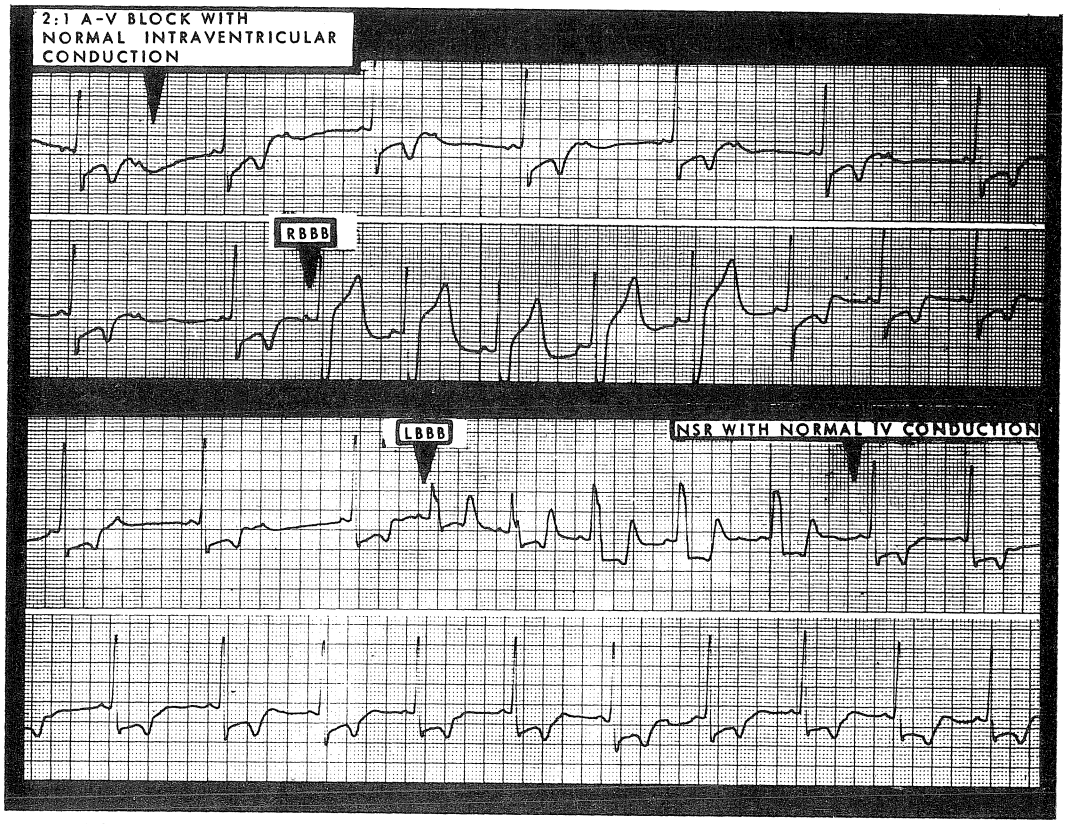

Fig 15.—Shifting A-V block and changing intraventricular conductions in an asymptomatic man of 60 (real-time write-out from taped record).

a large meal, and with fatigue they have developed no significant change in the complex and no evidence of disturbed conduction or of arrhythmia. Yet, two of these men have died suddenly with the clinical syndrome of acute myocardial infarction within several months after we have studied them.

Comment

The evidence to date indicates that changes in the ST segment and T wave vectors occur so frequently in people of all ages and both sexes, in association with ordinary activities and common physiologic states, that we believe it is hazardous to assume that they necessarily indicate the presence of a pathological process.

There is a strong suggestion that some people with unreactive and quite stable electrocardiographic patterns may be at least as susceptible to acute myocardial infarction or to sudden death as those with more labile patterns. On the other hand, the finding that asymptomatic men in their 50's, most of whom presumably have extensive coronary atherosclerosis, may exhibit pronounced arrhythmias and changes in intraventricular conduction during periods of anxiety, while ingesting a meal, or while engaging in ordinary activity, suggests that rather trivial events might possibly initiate serious episodes of arrhythmia, or even ventricular fibrillation and death, in people with damaged or partly impaired hearts.

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